

marks define closed loops at several points. Some of these loops have a larger radius of curvature than do others, suggesting perhaps that the diameter of the vortex was oscillating about a mean.

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REFERENCES

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CORRESPONDENCE

Comments On "A Synthesis of Interpretations of Extratropical Vortex Patterns As Seen by TIROS"

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Dr. Widger [1] has performed a valuable service by summarizing many papers that have treated the interpretation of satellite pictures. His list of 28 references is proof enough that this synthesis is needed by meteorologists who do not have the time or the need to study each paper individually. Two points in his summary, it seems to me, should be discussed.

Perhaps the most important is the dispersion of pictured cloud spiral centers about the atmospheric circulation center. Questions important to the meteorologists are: (a) Is the apparent dispersion the result of inaccurate determination of the satellite picture location or displacement of the analyzed low pressure center? (b) Is the dispersion the result of cloud patterns being embedded in atmospheric layers other than the surface or the 500-mb. levels in strongly sloping cyclones (see [1] fig. 13)? (c) Can the cloud spiral centers actually be significantly displaced from the circulation centers? The picture interpretation will differ markedly, depending upon the true state of affairs regarding questions a, b, and c.

There can be little doubt that *some* of the dispersion of cloud vortex centers about the low pressure center is due to inaccurate location of both picture and cyclonic circulation (e.g., see [2]). A hint of this conclusion is obtained by separating the dispersion statistics into two groups; one, those cases of spirals over land where the standard

data are dense, and two, those over ocean areas where the data are more widely separated. The former group exhibits less scatter. But the whole matter cannot be so simply explained.

Neither can the scatter of points in Widger's figure 13 a and b all be explained by the alternative that invokes the sloping axis of cold Lows. Although the height of the pictured clouds is frequently unknown, there is good evidence that many of these patterns lie *somewhere* between the surface and 500 mb. If sloping axes are the reason for displacement of the positions, it follows that the center of the pictured spiral pattern should lie on a straight line between the surface and 500-mb. Low positions. Many do not. Analysis of Widger's figure 13 shows that many of the cases shown there cannot be so positioned.

We are led to the conclusion that it is possible for spiral cloud patterns to exist when there is no actual closed vortex in the air flow. Indeed, an excellent example of this is described in his reference 9.

Widger [1] concludes on page 272 that, "Since a clearly definitive cloud vortex seems to require the existence of an upper-air circulation, better correspondence between the cloud vortex and upper-air vortex or trough . . . seems reasonable. . . ." This statement does not appear justified insofar as it seems to conclude an "upper-air-vortex" is required to produce a cloud spiral pattern.

The mechanisms that could produce such a pattern are several. The one discussed in reference 9 involves orientation of cloud bands along the vertical shear vector, thus along the thermal wind rather than the actual wind. Another mechanism involves lateral shear, but nothing

yet has been published on this suggestion.* Clearly further research on this problem is required. Investigation must be directed toward identifying the producing mechanism in each case for it is quite reasonable to believe more than one mechanism may exist in the real atmosphere.

The cellular cloud fields Widger discusses in the subsection on low-level winds are exciting because this particular scale of convective cells were not discovered or even suspected until April 1960 when TIROS I pictures were obtained!

These patterns are frequent over oceans but almost entirely absent from land areas. Consequently their nature and even their description are hampered by the lack of data over oceans—especially the measurements of vertical shear and stability. Theory, as well as experiments mentioned by Widger ([1] p. 278), indicates that these variables are critical and that wind speed by itself is less important. For that reason it can be quite misleading to correlate a small sample of cellular patterns with speeds. Further, study of cases in the Southern Hemisphere oceans reported by Merritt is further handicapped by the dearth of actual surface wind reports in the southern oceans. Geostrophic winds derived from surface analysis in the Southern Hemisphere were used where ship reports were not available. The results consequently must be viewed as tentative and preliminary.

A paper just published by van der Ham [3] discusses the interpretation of cellular patterns. He does not consider them as speed indicators but points out their close association with stability and heating of the air by a warm ocean surface.

Meteorologists working in the field of satellite data are coming more and more to realize that there is a large amount of meteorological information in the organization exhibited by cloud patterns. Progress in their interpretation is being made by many organizations, including the group working under Dr. Widger. Many results are no doubt being prepared for publication even as these lines are read. We can look forward to the need for another synthesis, perhaps by the same author, within the next few years.

REFERENCES

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2. L. F. Hubert and A. Timchalk, "Accuracy of TIROS Hurricane Locations," *Journal of Applied Meteorology*, vol. 3, No. 2, Apr. 1964, pp. 203–205.
3. C. J. van der Ham, "Satellite Cloud Pictures," *Weather*, vol. 19, No. 6, June 1964, pp. 180–189.

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REPLY

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Mr. Hubert and I are clearly in agreement on at least two points: (1) the value of summarizing significant areas of our currently existing knowledge, even when the state of that knowledge is far less than is to be desired; and (2) the continuing need for extensive basic and applied research on the significance and interpretations of the various vortical-appearing cloud patterns so frequently photographed by the meteorological satellites.

One source of the dispersion of pressure centers about the apparent cloud vortex centers as shown in figure 13 of [6] derives (as Mr. Hubert is well aware) from the "ground rules" of the study under which these statistics were developed. To quote from the Final Report [1] of that investigation:

"Emphasis was placed on oceanic cases, since it was believed that cloud vortex patterns would appear more clearly organized there and because such regions were felt to be more representative of the other data-sparse areas where interpretations of the satellite observations are particularly critical. In retrospect, the problems encountered regarding the accuracy of conventional analyses over the oceanic areas suggest that this emphasis may have been somewhat unfortunate."

A second source derives from the fact that figure 13 contains what is now known to be a heterogeneity of cases. Work conducted by Rogers, in parallel with the statistical determinations summarized in figure 13, has since clearly demonstrated "that it is possible for spiral cloud patterns to exist when there is no actual closed vortex in the air flow." These findings are discussed in section 5 of [1] and summarized on pages 265–266 and 269 of [6]. They emphasize the need for greater semantic clarity in discussions of these matters since there is no simple one-to-one relationship between the various types of vortical-appearing cloud patterns and the hydrodynamically significant pressure vortices. An obvious additional implication is the need for improved and objective ways to distinguish between such cases as those studied by Rogers and the "clearly definitive cloud vortex" discussed on page 272 of [6].

The paper [6] discussed by Mr. Hubert was clearly stated as "an attempt to integrate existing published knowledge" and made no pretense of providing a final solution to these problems. But quoting again from [1]:

"These studies have re-emphasized the complexity and variety of cloud vortex patterns, and our serious lack of anything approaching an adequate understanding of what various vortices really signify. While many vortices appear clearly associated with the development sequence proposed by the Boucher-Newcomb model (although not always starting with the initial stages of that model),

*From Dr. R. S. Scorer, Imperial College, London, Private communication.